UNIVERSITI KUALA LUMPUR
MALAYSIAN INSTITUTE OF MARINE ENGINEERING TECHNOLOGY

FINAL EXAMINATION
JANUARY 2017 SEMESTER

COURSE CODE	:	LGB31503
COURSE NAME	:	THERMODYNAMICS
PROGRAMME NAME (FOR MPU: PROGRAMME LEVEL)	:	BACHELOR OF ENGINEERING TECHNOLOGY (HONS) IN NAVAL ARCHITECTURE & SHIPBUILDING
DATE	:	06/07/2017 THU
TIME	:	9.00 AM - 12.00 PM
DURATION	:	3 HOURS

INSTRUCTIONS TO CANDIDATES

1. Please read CAREFULLY the instructions given in the question paper.
2. This question paper has information printed on both sides.
3. This question paper consists of TWO (2) sections; Section A and Section B. Answer ALL questions in Section A and THREE (3) questions from Section B.
4. Please write yours answers on the answer booklet provided.
5. Write your answers only in BLACK or BLUE ink.
6. Answer all questions in English.

THERE ARE 5 PAGES OF QUESTIONS, EXCLUDING THIS PAGE.

SECTION A (Total: 40 marks)

INSTRUCTION: Answer ALL questions.
Please use the answer booklet provided.

Question 1

The area of a compressed air storage tank is 0.5 m^2 with a force of 600 kN. Express this tank's pressure in kPa and convert into the following units:

i. mmHg

ii. lbf/in^2

(8 marks)

Question 2

Define kinetic energy and potential energy. Write the equations and the units for both energies.

(8 marks)

Question 3

Tabulate completely the specific properties of refrigerant-134a (R-134a) as shown in Table 1. (Hint: show all calculations/method involved)

Table 1: Specific properties of R-134a

T, ^0C	P, kPa	v, m^3/kg	Phase description	Quality, x
- 4	320			
10		0.0065		

(8 marks)

Question 4

Write short notes about nozzles and diffusers. You may sketch schematic illustrations for these engineering devices.

(8 marks)

Question 5

Describe FOUR (4) main components of steam power plant having Rankine cycle.

(8 marks)

SECTION B (Total: 60 marks)

INSTRUCTION: Answer only THREE (3) questions.
Please use the answer booklet provided.

Question 6

A 0.7 m^3 rigid tank contains refrigerant-134a initially at 180 kPa and 40 percent quality. Heat is now transferred to the refrigerant until the pressure reaches 700 kPa. Determine the following:

i. The mass of the refrigerant in the tank.

(7 marks)

ii. The amount of heat transferred.

(13 marks)

Question 7

Steam at 3 MPa and 400°C enters an adiabatic nozzle steadily with a velocity of 40 m/s and leaves at 2.5 MPa with a velocity of 300 m/s as shown in Figure 1.

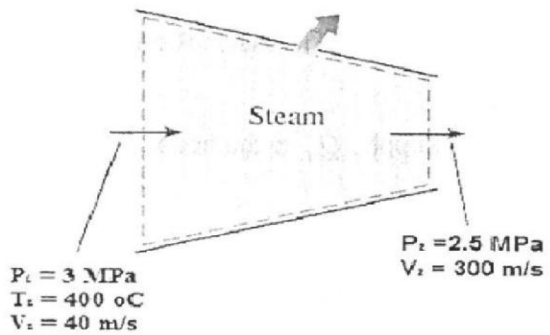

Figure 1: Nozzle system

i. Determine the exit temperature, T_{exit}.

(11 marks)

ii. Determine the ratio of the inlet to exit area, $\frac{A_1}{A_2}$.

(9 marks)

Question 8

A heat pump used to heat a house operates on an ideal vapor-compression refrigeration cycle with refrigerant-134a as the working fluid as shown in Figure 2. The condenser and evaporator pressures are 0.9 and 0.2 MPa, respectively while the mass flow rate of the refrigerant is 19.2 kg/min.

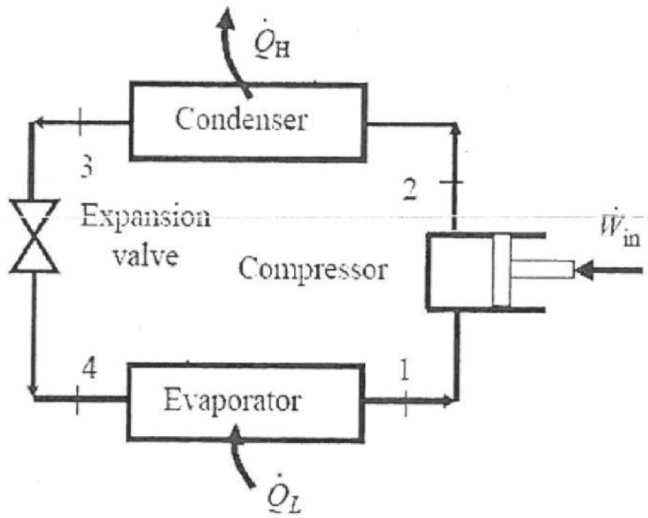

Figure 2: Ideal Vapor-Compression Refrigeration Cycle

i. Determine the rate of heat supply, $\dot{Q}_H$ to the house.

(13 marks)

ii. Calculate the volume flow rate of the refrigerant at the compressor inlet, $\dot{V}_1$

(4 marks)

iii. Determine the coefficient of performance, COP_{HP} of the heat pump, and

(3 marks)

Question 9

A four-cylinder spark ignition engine has a compression ratio of 10.5, and each cylinder has a maximum volume of 0.4 L. At the beginning of the compression process, the air is at 98 kPa and 37 °C, and the maximum temperature in the cycle is 2100 K. Assume the engine operates on the ideal Otto cycle and variable specific heats are used for air.

i. Show the said processes in T-s diagram with respect to the saturation lines.

(3 marks)

ii. Calculate the amount of heat supplied, Q_{in}, and heat rejection, Q_{out}, per cylinder in kJ.

(17 marks)

END OF EXAMINATION PAPER

THERMODYNAMICS FORMULA

First Law of Thermodynamics
$KE = \frac{mV^2}{2}$
$PE = mgz$
$E_{in} - E_{out} = (Q_{in} - Q_{out}) + (W_{in} - W_{out})$
$\Delta E_{system} = \Delta U + \Delta KE + \Delta PE$
$Q = \dot{Q}\Delta t$
$Electrical\ power,\ \dot{W}_e = VI\ (kW)$
$Electrical\ work,\ W_e = VI\Delta t\ (kJ)$
$W = Fs$
$Shaft\ work,\ W_{sh} = 2\pi nt$
$F = kx$
$F = PA$
$Spring\ work,\ W_{spring} = \frac{1}{2}k({x_2}^2 - {x_1}^2)$
$H = U + PV$
$Quality,\ x = \frac{m_g}{m_{total}}$
$m_{total} = m_f + m_g$
$v_{fg} = v_g - v_f$
$v_1 = v_f + x_1 v_{fg}$
$u_1 = u_f + x_1 u_{fg}$
$Pv = RT$
$PV = mRT$
$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
$Pv = ZRT$

$W = W_b = \int_1^2 P dV$
$w = Pv$
Entropy
$dS = \left(\frac{dQ}{T}\right)_{\text{int } rev}$
$\Delta S = \frac{Q}{T_o}$
$S_{gen} \geq 0$
$s_2 - s_1 = c_{avg} \ln \frac{T_2}{T_1}$
$s_2 - s_1 = c_{v,avg} \ln \frac{T_2}{T_1} + R \ln \frac{v_2}{v_1}$
$s_2 - s_1 = c_{p,avg} \ln \frac{T_2}{T_1} - R \ln \frac{v_2}{v_1}$
$s_2 - s_1 = s^o{}_2 - s^o{}_1 - R \ln \frac{P_2}{P_1}$
$w_{rev} = -\int_1^2 v dP - \Delta ke - \Delta pe$
$w_{rev} = -v(P_2 - P_1) - \Delta ke - \Delta pe$
(isentropic) $w_{comp,in} = \frac{kR(T_2 - T_1)}{k-1} = \frac{kRT_1}{k-1}\left[\left(\frac{P_2}{P_1}\right)^{(k-1)/k} - 1\right]$
(polytropic) $w_{comp,in} = \frac{nR(T_2 - T_1)}{n-1} = \frac{nRT_1}{k-1}\left[\left(\frac{P_2}{P_1}\right)^{(n-1)/n} - 1\right]$
(isothermal) $w_{comp,in} = RT \ln \frac{P_2}{P_1}$
$\eta_T = \frac{w_a}{w_s} \cong \frac{h_1 - h_{2a}}{h_1 - h_{2s}}$
$\eta_C = \frac{w_s}{w_a} \cong \frac{h_{2s} - h_1}{h_{2a} - h_1}$

$\eta_P = \frac{w_s}{w_a} = \frac{v(P_2 - P_1)}{h_{2a} - h_1}$
Carnot Heat Engine
$\eta_{th,Carnot} = \eta_{th,rev} = 1 - \frac{T_L}{T_H}$
Isentropic Process
$s_2 = s_1$
$\left(\frac{T_2}{T_1}\right)_{s=const.} = \left(\frac{v_1}{v_2}\right)^{k-1}$
$\left(\frac{T_2}{T_1}\right)_{s=const.} = \left(\frac{P_2}{P_1}\right)^{(k-1)/k}$
$\left(\frac{P_2}{P_1}\right)_{s=const.} = \left(\frac{v_1}{v_2}\right)^{k}$
$\left(\frac{P_2}{P_1}\right)_{s=const.} = \frac{P_{r2}}{P_{r1}}$
$\left(\frac{v_2}{v_1}\right)_{s=const.} = \frac{v_{r2}}{v_{r1}}$
Power Cycles
$r = \frac{V_{max}}{V_{min}} = \frac{V_{BDC}}{V_{TDC}} = \frac{V_1}{V_2} = \frac{v_1}{v_2}$
$MEP = \frac{W_{net}}{V_{max} - V_{min}} = \frac{w_{net}}{v_{max} - v_{min}}$
Otto Cycle
$(q_{in} - q_{out}) + (w_{in} - w_{out}) = h_{exit} - h_{inlet}$
$q_{in} = u_3 - u_2 = c_v(T_3 - T_2)$
$q_{out} = u_4 - u_1 = c_v(T_4 - T_1)$
$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{k-1} = \left(\frac{v_3}{v_4}\right)^{k-1} = \frac{T_4}{T_3}$
$\eta_{th,Otto} = \frac{w_{net}}{q_{in}} = 1 - \frac{q_{out}}{q_{in}}$

$\eta_{th,Otto} = 1 - \frac{1}{r^{k-1}}$
Diesel Cycle
$q_{in} = w_{b,out} + (u_3 - u_2) = P_2(v_3 - v_2) + (u_3 - u_2) = h_3 - h_2 = c_p(T_3 - T_2)$
$q_{out} = u_4 - u_1 = c_v(T_4 - T_1)$
$r_c = \frac{V_3}{V_2} = \frac{v_3}{v_2}$
$\eta_{th,Diesel} = 1 - \frac{1}{r^{k-1}}\left[\frac{r_C^k - 1}{k(r_C - 1)}\right]$
Rankine Cycle
$w_{pump,in} = h_2 - h_1 = v(P_2 - P_1)$
$q_{in} = h_3 - h_2$
$w_{turb,out} = h_3 - h_4$
$q_{out} = h_4 - h_1$
$\eta_{th} = \frac{w_{net}}{q_{in}} = 1 - \frac{q_{out}}{q_{in}}$
$w_{net} = q_{in} - q_{out} = w_{turb,in} - w_{pump,in}$
$x_4 = \frac{s_4 - s_f}{s_{fg}}$
$h_4 = h_f + x_4 h_{fg}$
Refrigeration Cycle
$\dot{Q}_L = \dot{m}(h_1 - h_4)$
$\dot{Q}_H = \dot{m}(h_2 - h_3)$
$\dot{W}_{in} = \dot{m}(h_2 - h_1)$
$W_{in} = Q_H - Q_L$
$COP_R = \frac{Q_L}{W_{net,in}} = \frac{q_L}{w_{net,in}} = \frac{Q_L}{Q_H - Q_L} = \frac{h_1 - h_4}{h_2 - h_1}$
Heat Pump

$COP_{HP}=\frac{Q_H}{W_{net,in}}=\frac{q_H}{w_{net,in}}=\frac{Q_H}{Q_H-Q_L}=\frac{h_2-h_3}{h_2-h_1}$
$COP_{HP}=COP_R+1$
Total Pressure
$P=P_a+P_v$ (kPa)
Partial Pressure of Water Vapor
$P_v=\phi P_g=\phi P_{sat@T}$
Specific Humidity of Air
$\omega=\frac{m_v}{m_a}=\frac{P_vV/R_vT}{P_aV/R_aT}=\frac{P_v/R_v}{P_a/R_a}=0.622\frac{P_v}{P_a}$
$\omega_2=\frac{0.622P_{g_2}}{P-P_{g_2}}$ (kg water vapor/kg dry air)
$\omega_1=\frac{c_p(T_2-T_1)+\omega_2h_{fg_2}}{h_{g_1-h_{f_2}}}$
Relative Humidity of Air
$\phi_1=\frac{m_v}{m_a}=\frac{P_vV/R_vT}{P_gV/R_vT}=\frac{P_v}{P_g}$ where $P_g=P_{sat@T}$
$\phi_1=\frac{\omega_1P_1}{(0.622+\omega_1)P_{g_1}}$
Enthalpy of Air
$H=H_a+H_v=m_ah_a+m_vh_v$
$h=h_a+\omega h_g\cong c_pT+\omega h_g$ (kJ/kg dry air)